Evaluation of a Digital Map Platform for Team Situational Awareness

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ABSTRACT

Currently, emergency responders are utilizing several different digital platforms with limited interoperability. This can lead to miscommunication and misunderstandings between emergency responders. The digital map software Square is designed to mitigate this by providing a unified platform for emergency responders to facilitate sharing of information. With a large and diverse potential user group, it is important that the system is accessible and intuitive to use for as many users as possible, particularly in high-stress situations. The user testing and interview in this study provides insights into how new users interact with the software. The Square platform presented significant barriers to efficient use, and the findings from this study are used to improve the usability and accessibility in the forthcoming updates to Square.

Keywords

Team situational awareness, shared maps, usability, universal design, situational disabilities, SA demons.

INTRODUCTION

In today's digital age, digital maps are integral to daily life. For quick location information, Google Maps on mobile devices is a go-to resource. Besides, many sectors have embraced digitalization for improved efficiency and inter-departmental communication. However, emergency management lags in this transition. Emergency management involves police, fire departments, ambulances, hospitals, volunteer agencies, and government bodies. Although each has its digital tools, these often lack interoperability, leading to poor information exchange (Rustenberg & Steen-Tveit, 2023). Therefore, there is a need for a common platform among emergency responders. Square is a map-based tool designed as a unified platform for emergency responders to facilitate sharing of information and promote *team situational awareness*, i.e. a common understanding of the situation at hand, in order to make the right decisions in complex situations. Square is at the time of testing fully functional and feature complete, but the developers consider that it still has room for improvement concerning user-friendliness and intuitiveness in use.

Universal Design – the design of systems to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design, is particularly important for applications used in emergency management (Gjøsæter et al., 2020b; Radianti et al., 2017). While a minority of emergency management personnel have disabilities, milder disabilities like colour-blindness are not uncommon. In addition, so-called *situational disabilities* can be prevalent in stressful situations (Gjøsæter et al., 2019). Map-based tools like Square can typically be particularly challenging regarding Universal Design, especially for people with reduced vision or color-blindness (Hasan & Gjøsæter, 2021; Tunold et al., 2019).

An essential aspect of Universal Design, especially when it comes to mitigation of Situational Disabilities, is *usability*. The goal of this study is therefore to perform a usability evaluation of the Emergency Management software Square from a universal design perspective.

The evaluation of Square aims to address two main research questions:

- RQ1: What barriers and usability limitations exist in the digital emergency management map system Square?
- RQ2: What disabilities, permanent, temporary or situational, are most severely affected by these barriers?

The rest of this paper is organized as follows. The Introduction section is followed by an overview of Square, including its main pages and core functions to provide context for this study, and a brief Literature Review. The Method section provides details of the research design and ethical considerations. The Results section presents the findings from the user testing and interviews. The Discussion section addresses the two research questions and discusses the limitations of the study. The last section concludes the paper and presents directions for future work.

SQUARE

Square is an in-development project from the University of Agder. Researchers have recognized from evaluations and interviews that current solutions fail to facilitate collaboration effectively, often leading to misinformation (Rustenberg & Steen-Tveit, 2023). This has motivated the development of Square, aiming to serve as a unified communication platform for emergency responders.

Square is a digital map service designed for emergency responders to create, mark, and share detailed incident information, such as event location and actions underway, with one another. Figure 1 shows an example of the Square interactive event map.

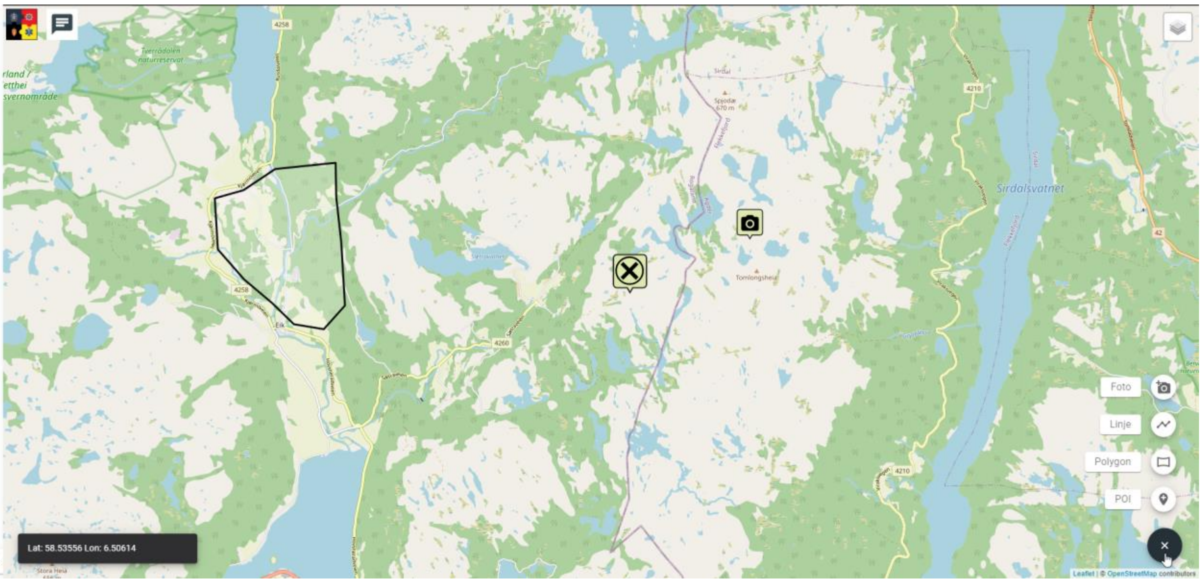

Figure 1. Square interactive map.

Square is intended for use primarily during the Response stage to support coordinated efforts among emergency responders. However, operators must be familiar with the software, necessitating training during the Preparedness stage. Additionally, the tool can serve as a reference in the Recovery stage, helping identify damage locations and restoration needs. By providing a unified mapping service, Square aims to minimize misinformation and enhance communication accuracy among responders.

The pages of Square

Square requires you to be logged in and have an established user account. The login sequence requires your phone number as your unique username. Once you type in your phone number you will receive a pass key through a text message.

Once the login sequence is complete, the user is taken to the home page which can be seen in Figure 2. The Home page is where a user accesses all functionality in Square. At the top there is a group of 4 buttons, these will take users to new pages. The top left button will start the creation of a new event, the top right button takes users to a page to send message to the group, the bottom left button takes users to a page listing all members of a group and the bottom right takes users to a page where they can choose from lists of finished events (i.e. events that has been closed when the crisis is over or the exercise is finished) to evaluate. Underneath the group of buttons are two lists, one containing the most recent open events and another containing the last 5 messages sent to the group.

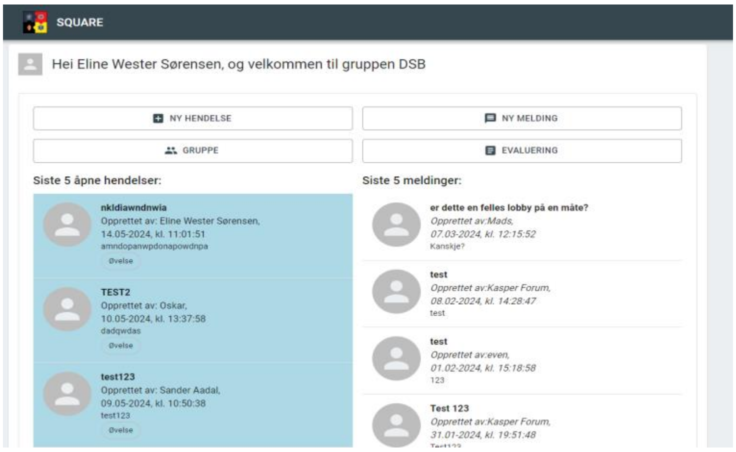

Figure 2. The Square home page.

The logo of Square on each page functions as a button that brings up a sidebar menu (see Figure 3). This side bar is where users can see their own information, access the page to edit their profile, log out, or return to the home page,

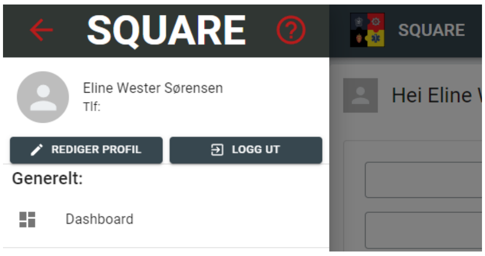

Figure 3. The Square side bar menu.

Upon clicking the "Create New Event" button, users are directed to the page shown in Figure 4. Here they are expected to choose a location for the event. The first input field is a search bar to find a location, and then the map is for more precise location selection. Users can enter a title and a brief description of the event. Additional options include marking the event as a training exercise and setting visibility for others. The page also includes "Start Event" and "Cancel" buttons located below these options. Pressing "Start Event" leads users to the event map displayed in Figure 1.

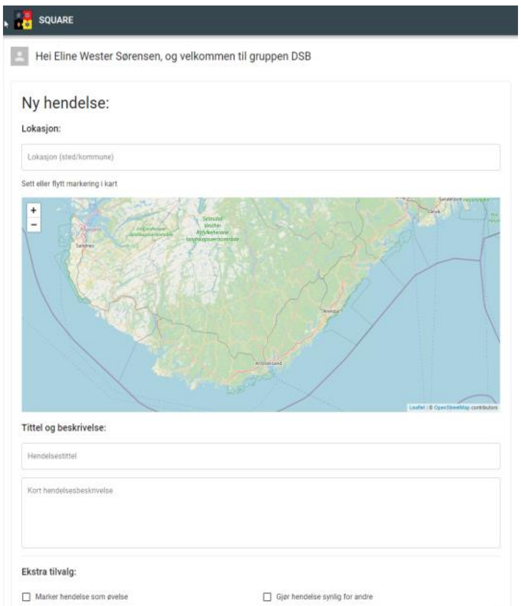

Figure 4. The event creation page.

Once an event is finished, the evaluation selection page will show two lists of interactable elements. The first list shows events that have finished but are not in the evaluation process, and the other shows a list of events currently under evaluation. The user can click on any of these listed elements to be shown a summary of an event and then click on a button to start the evaluation as seen in Figure 5.

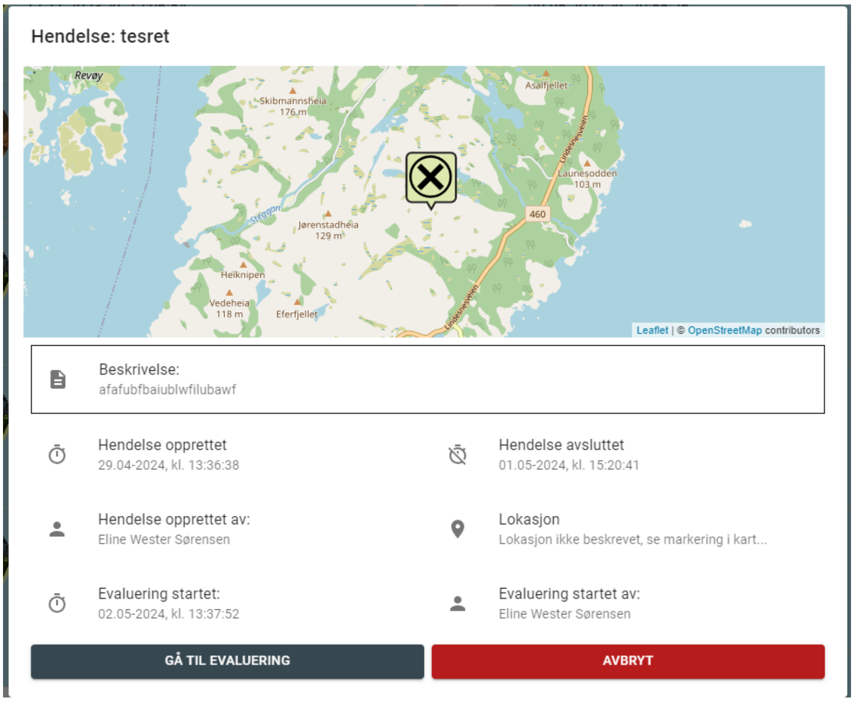

Figure 5. Event summary in the evaluation selection page.

In the evaluation, users are first faced with a pop-up form with multiple pages, each with several input fields where one can evaluate the event with different prompts in each input field. Each page features a backward and forward button with a percentage bar indicating degree of completion.

If the user closes the evaluation form, they are met with a map, including all the markers that were placed during the event as shown in Figure 6. Below the map, the user can find a timeline of events that can be played to show when different markers were placed on the map. The user can pause and start the timeline, and it is by default paused. They can also skip backward and forward and change the playback speed. Two entries show when the event was started and ended.

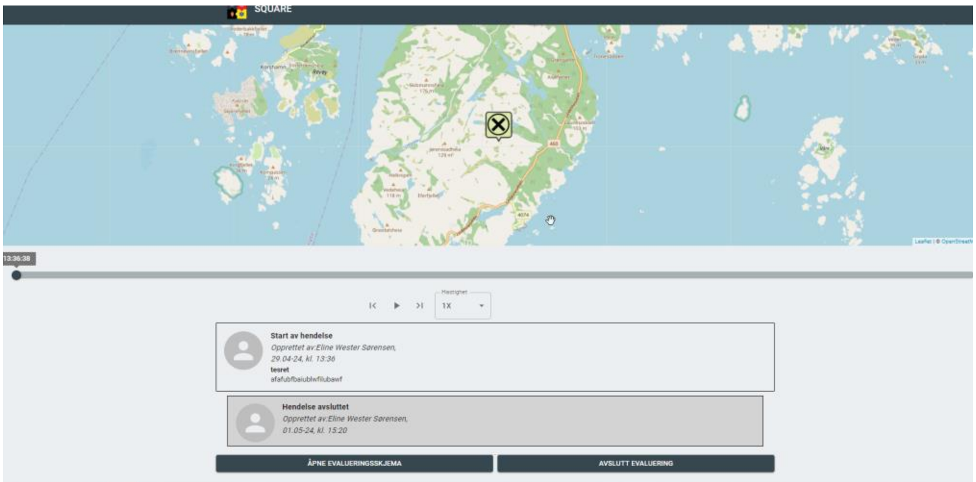

Figure 6. The timeline on the evaluation page.

LITERATURE REVIEW

In this section we will cover three relevant topics from previous research that highlight different aspects of usability, barriers and universal design of map-based platforms for shared situational awareness.

Firstly, we will be looking at previous research on digital map solutions with a particular focus on usability and Universal Design, to understand the inherent challenges and common barriers this entails. Second, we investigate *situational awareness*, how it is established and maintained, and third, barriers like *situational disabilities* and *demons of situational awareness* and how to tackle and overcome them in a stressful situation.

Universal Design Analysis of Digital Maps

Digital maps have become ubiquitous in today's society, with apps like Google Maps providing detailed global coverage. However, their visual nature poses challenges for visually impaired users. For instance, blind individuals often face difficulties as screen readers and keyboard controls do not effectively interact with digital maps (Hasan & Gjøsæter, 2021).Physical maps can be made tactile, using Braille or raised elements to indicate features like elevation or separations in urban areas, but these are time-intensive to produce.

Tunold et al. evaluated the accessibility of two digital maps for users with low vision: a Disaster Alert Map from the PDC covering Pacific Ocean tsunamis and earthquakes, and the #OneMillionTweetMap tracking Twitter activity by location. Their study followed the Web Content Accessibility Guidelines (WCAG) 2.1, assessing the perceivability through manual and automatic color testing, in addition to expert evaluation by a low-vision user. They found significant barriers, particularly related to color contrast, keyboard navigation, and pop-up windows (Tunold et al., 2019). Among literature on digital maps in emergency management, we have identified a gap when it comes to focus on usability and universal design. For example, in eight papers in the ISCRAM Digital Library containing the word "Maps" in the title, only two of these discuss user friendliness or usability, and then only tangentially. Lijnse (2019) mentions briefly the lack of user-friendliness in configuration of map-rendering in an application, i.e. not end-user usability but developer usability. Willems and Vuurpijl (2007) discuss usability of interactive maps in emergency management, but only from a future work perspective.

Situational Awareness, Team Situational Awareness and Common Operational Picture

Situational awareness is vital in emergency management, though its definition varies by sector and whether it is individual or team-based (Gjøsæter et al., 2020a).

For individual situational awareness, Endsley (1995)' s widely-cited model outlines three levels:

1. **Perception**: Recognizing key elements in the environment.
2. **Comprehension**: Integrating these elements to understand their significance.
3. **Projection**: Using this understanding to predict future developments.

Team situational awareness builds on individual awareness, emphasizing collaboration. Endsley (2001) identified three critical team features:

1. **Common Goal**: A unified objective.
2. **Interdependence**: Reliance on each other for success.
3. **Specific Roles**: Distinct tasks for each member, which provide the situational awareness elements they are concerned with.

Common operational picture tools typically combine data from different subsystems and present the resulting information into an overview for facilitating situation awareness among diverse actors in emergency operations (Björkbom et al., 2013). Opach et al. (2020) discuss map-based common operational picture tools and point out that they are often developed from non-user-centric perspectives and are defined in technological terms and are not adequately capturing the users' needs.

Barriers, Situational Disabilities and Demons of Situational Awareness

There are factors that can hinder situational awareness. *Situational disabilities* are conditions that can affect a user's ability to complete their tasks due to environmental conditions and the situation where the task is conducted (Nicolau, 2012; Saulynas et al., 2017; Shum et al., 2016; Tigwell et al., 2019; Wobbrock, 2019). The term was originally coined as “situationally-induced impairments and disabilities" or SIID by Sears et al. (2003).

When using Square during emergencies, certain factors may induce situational disabilities. Given that Square is employed in crisis scenarios, it is crucial to consider potential situational disabilities users might encounter. Gjøsæter et al. (2019) suggest that information overload, stress, and panic can result in situational cognitive disabilities. This could impair users' decision-making or software operation. Therefore, the software must be intuitive and easy to use, even under reduced cognitive functionality, to prevent cognitive overload.

A key aspect of situational awareness involves addressing Endsley's situational awareness demons, barriers that can undermine or prevent situational awareness (Endsley, 2003). According to Gjøsæter et al. (2019), there is a clear link between these demons and situational disabilities. They are:

- **Attentional Narrowing**: Focusing too intently on a single task, neglecting other important elements. Emergency management systems should enable multitasking.
- **Requisite Memory Trap**: Forgetting tasks or overloading short-term memory. Systems should minimize reliance on operators remembering critical information over multiple interactions.
- **Workload, Fatigue, and Stressors**: High stress, fatigue, or pressure diminishes capabilities, reducing memory capacity and disrupting information acquisition.
- **Data Overload**: Excessive, rapid data can overwhelm an operator's mental processing.
- **Misplaced Salience**: Overemphasis on visual features can misdirect attention.
- **Complexity Creep**: Overly complex system actions hinder situational awareness and prediction.
- **Errant Mental Models**: Misinterpretation due to mismatches between operators' understanding of system functions and reality.
- **Out-of-the-loop Syndrome**: High automation may reduce operators' awareness of system status.

4. METHOD

To gather feedback from potential end users, we conducted user testing and interviews on Square. These users, not being experts in universal design, may not fully grasp the concept. However, the focus was on analyzing their behavior and identifying any issues they encountered. Subsequently, participants were interviewed about their experiences with Square and similar software.

Participants

For this study, we recruited four participants for both user testing and interviews, through professional channels. Participants included experts in emergency management and software development. Each participant was individually interviewed. Below is a table detailing their demographic information. None of the participants had disabilities or impairments that could have affected their task performance. All had access to and used both a keyboard and mouse during the test. Of the four participants, P1 and P3 were bilingual in Norwegian and English, while P2 and P4 only spoke English. However, P4 could read some Norwegian.

Table 1: Background information on the participants

	Gender	Age	EM experience	EM software experience	Computer experience	Handling stress
P1	Female	40	Extremely good	Extremely good	Decent	Well
P2	Male	33	Good	Little	Very good	Very good
P3	Female	39	Extremely good	Good	Very good	Very good
P4	Non binary	30	Decent	Decent	Decent	Good

Due to logistical constraints, all interviews were conducted online via Zoom. Participants signed a consent form before participating, which granted permission to record the interviews and informed them of the storage and eventual deletion of these recordings. Other than their voices, no personal details were collected. The study has been approved by SIKT (the Norwegian Agency for Shared Services in Education and Research).

User Testing Scenario

During user testing, participants were asked to explore relevant features of the Square system. They first needed to create an account, which was a prerequisite due to the online testing format via Zoom.

After setting up their accounts, participants shared their screens, and one of the authors, guided them through tasks showcasing the software's functionalities. In a given scenario, participants were asked to create an event about a wildfire in the forest near Kristiansand, using all tools available in Square. Since Square is only available in Norwegian, some guidance were needed for English-speaking participants.

The first task involved finding the "Ny hendelse" button to create a new event. Participants then marked an origin point, created an event title, and described the scenario. To select an event location, participants had two options: utilizing the "Lokasjon" search function to add a map pin or placing a pin directly on the map.

After creating the event, participants were asked to use the tools to create an area indicator reflecting the fire's spread. They then used another tool to place a Point of Interest (POI). The content of the POI was not important; the focus was on the participant's ability to locate and place it correctly. When the POI tool was activated, participants encountered a menu, including the "velg type POI" dropdown menu, demonstrated in the session. This step aimed to gather feedback on the graphics and interface—whether the categories were intuitive and if participants could easily find the appropriate POI type for their chosen objective.

Next, participants were instructed to switch the map display from street view to topographical, with options to layer water lines and critical infrastructure maps. They then explored the built-in chat feature on the map/event page to assess its layout, ease of access, message sending, and categorization options.

Finally, participants were asked to close and end the event by navigating back to the home page using the top-right menu button and selecting "avslutt hendelse." Once on the home page, they were prompted to start an event evaluation, a standard procedure for first responders after emergencies. Although the evaluation content was not emphasized, interaction with this feature was encouraged. Participants also reviewed an event timeline, providing feedback on its presentation.

Interviews

The study utilized a semi-structured interview format. The interview guide, developed by the research team, comprised 16 questions across three sections.

The first section gathered demographic data for later analysis. In sections two and three, participants were asked follow-up questions about the user testing. The second section solicited opinions on Square, identifying positives, negatives, areas for improvement, information presented, and whether this information would be manageable in stressful situations. The third section explored participants' experiences with similar software and how those experiences compared to using Square.

Interviews were audio-recorded, allowing the interviewer to focus on a naturally flowing conversation and ensuring efficiency for participants.

Data Analysis

To analyze participants' interview responses, we adopted an inductive approach. This involved identifying common themes within their answers and coding responses into statistical data. This method provides a clearer overview and helps uncover patterns and trends across participants' feedback.

Ethical Considerations: Data Management

To comply with national guidelines for handling personal information in research, interview audio recordings were stored securely to protect participant data. Access is restricted to the research team. Upon completion of the project, all recordings will be permanently deleted to maintain participant privacy.

5. RESULTS

In this chapter we will present the results of the user testing observation, the users feedback and their answers in the interviews.

User Testing Observations

The user testing results varied significantly among participants. A notable issue was that the software was only available in Norwegian. P2 struggled with tasks requiring text comprehension, needing extensive guidance. P4, while able to read some Norwegian, managed tasks with minimal help.

All participants encountered difficulties during event creation. P1 initially used the map for location selection before trying the search field, indicating confusion about their connection. P2 had similar issues, likely due to language barriers. P3 mistakenly used the location search bar for the event title but quickly corrected themselves. P4 navigated the event creation without issues. Finding the map actions also posed a challenge to all participants. They experimented with various buttons before noticing the "+" button for map actions. The polygon tool presented different challenges: P1 and P2 attempted to drag to create a box, eventually figuring out the tool. P3 and P4, experienced with map software, found the lack of an undo feature frustrating. P4 also uncovered a bug when moving points. Instructions for the polygon tool were overlooked, with P3 noting its color similarity to the map made it hard to see.

After identifying the map actions, placing a POI was easier, though P2 initially struggled. Opinions on POI symbols were mixed. P1 found the selection overwhelming; P3 did not. None noticed that the icon selector's input field was a search bar. Participants located the chat feature relatively easily, with some recalling it from earlier exploration. There was consensus that categorizing messages post-sending was odd. P3 and P4 wished that category colors distinguished messages in the chat.

Participants experienced significant difficulty ending an event, as the option was hidden in a sidebar menu they rarely used. Only P4 quickly located it, having previously explored the menu while searching for map actions. Despite this, everyone easily navigated to the evaluation from the home page and identified their event for evaluation. Participants found the evaluation process straightforward, though it was too easy to accidentally click out of text boxes. This issue was mitigated by the program's regular saving feature. P3 and P4 expressed frustration with the buttons in the text box moving between pages, preferring a static button layout to prevent accidental closures.

Interview Results

All participants opted to conduct the interview in English, despite two being fluent in Norwegian. The responses remain untranslated for accuracy, although technological limitations, especially P2's poor audio equipment, made transcription difficult. Given the semi-structured interview format, participants sometimes preempted later questions with earlier responses, so questions were adjusted to avoid repetition. P1 was uniquely asked about Square in a professional emergency management context, as they were the only participant with relevant experience.

Initial questions focused on participants' immediate impressions of Square during testing. P1, P2, and P3 found it generally intuitive. P3's familiarity with similar software enhanced their experience, while P4 found it only partially intuitive, suggesting improved UI color use for navigation and noting the polygon tool's unintuitiveness.

Regarding difficulties with Square, P1 wanted centralized access to actions and buttons, preferring a hotbar to minimize search time. P3 found the color palette bland, complicating transitions in the chat and map, and criticized the polygon tool instructions. P2 mistakenly noted the chat box's position, which was where they preferred it, highlighting possible interface confusion.

All participants felt the information was manageable. However, in stressful situations, they were uncertain of their own capability, though they believed experienced users would cope better. P3 suggested UI improvements for high-stress contexts.

When asked about integrating Square into current emergency management solutions, P1 saw potential but emphasized the need for regular use to ensure proficiency during crises: "It has to be used regularly, like on a daily basis."

In comparing Square to other emergency management software, only P1 had practical experience. They found existing systems superior, notably in map visualization options like colors, topography, and aerial images.

P3's research experience with OpenStreet for emergency management recovery noted similar software quality, with OpenStreet having better visuals. P2 and P4's relevant software interactions were limited to navigation tools like Google Maps.

DISCUSSION

In this section, we will discuss the results as a whole and provide suggestions on how the design of the website can be improved based on the results presented in the previous section.

The number of participants in the user testing was found a little lacking and the data cannot be extrapolated necessarily to determine anything concretely. The use of user testing and interview did however lead to identifying some shortcomings and gave some recommendations to how the software may be improved. The rest of the discussion will focus on using the results to answer the two research questions.

RQ1 – What Barriers Exist in a Digital Map System Designed for Emergency Management?

We have uncovered a number of different barriers and shortcomings related to the use of Square.

To all users, the biggest barrier that Square has at the moment to an enjoyable user experience is the lack of error messages. There is also very little error prevention present in the input where specific input is required. An error prevention example is not giving the user access to input that is not valid. In both the phone number and passkey part of the login sequence the user is just expected to write numbers but the user has the ability to type in any character they want and are not restricted in any way. Implementing error messages and error prevention element where the user is expected to give specific input would greatly improve the user experience for all users.

The user testing exposed a key barrier to the software which is the language of the software. As it currently stands the software expects that all users are able to at least read Norwegian which became complicated for two of the participants who did not read Norwegian. However, for people who can read Norwegian, the language used was simple and understandable and would likely not create issues. The POI marker did not follow the established language expectations and used an English shortening of a term instead of a Norwegian term.

Another barrier to use of the program properly was also uncovered during the user testing. When trying to place down markers like POI, Polygon, Line and Photo, many of the users did not notice the instructions on how to use the tool. In the case of the Polygon and Line tools, the user also needed to interact with this instruction field to save or cancel the placement. It was also discovered that a user can leave the polygon and line actions and not save them. The fact that user testers so often missed the instructions that appeared, indicated that this is poorly placed or formatted so that it can easily fall outside of a user's focus and lead to potential errors or mistakes in their operation of the program. Especially in hectic or stressful situations – which is where the software is intended to be used.

RQ2 – What Disabilities are Most Severely Affected by These Barriers?

Individuals with visual impairments may face challenges using this application, as its core functionality relies on a map. Literature indicates that visually impaired users often encounter barriers with digital maps because of lacking screen readers and keyboard control support. This is indeed currently the case with Square as well. The event map is impossible to navigate using just a keyboard as a lot of the functionality require the use of a mouse, like placing down markers or areas.

Although we were not able to test user interaction under stress, several barriers for situationally disabled users due to stress are evident. Stress can induce temporary cognitive impairments, hindering software operation, and cause tunnel vision, making users miss essential details (Gjøsæter et al., 2019). Designers of software for use in emergency management has a particular responsibility to implement safeguards to ensure usability under stress. The absence of error messages and preventive measures significantly affects these users, who may overlook key tasks. For instance, instructions outside a typical visual range and difficult to notice due to poor color contrast can be easily missed, as noted during user testing. Another significant barrier is the lack of feedback. Providing clear feedback helps users correct mistakes without figuring out errors independently.

Limitations of This Study

One of the limitations of this study is the very limited number of participants in the user testing and interview. It also proved very difficult to reach professionals working in the EM field within the limited time frame of this project. Therefore, the participants were recruited among experts in EM with knowledge in software engineering rather than EM professionals. Although they have a more theoretical approach to EM than practitioners would have, they are deemed to be sufficiently knowledgeable in the practicalities in the field and familiar with relevant use cases for the Square software.

Another limitation is that Square was only available in Norwegian. This posed a challenge, as some participants struggled with the language, making certain interface elements that might have been intuitive less so. As a result, some participants required guidance throughout the test rather than independently exploring the software. This likely affected the results of the user testing by reducing the opportunity to observe natural interactions and spontaneous problem-solving.

CONCLUSION AND FUTURE WORK

This study aimed to identify barriers in the digital mapping software Square for Emergency Management and assess the types of disabilities affected by these barriers. Our testing revealed that Square, in its current state, presents critical challenges across multiple interaction categories and lacks key features that would enhance usability. These barriers not only create difficulties for certain user groups but may also impact individuals who experience situational disabilities due to the stressful situations in which Square is intended to be used.

Moving forward, the developers of Square should prioritize addressing the issues identified in this study. The most pressing improvements should focus on barriers that affect users who may experience situational disabilities due to stress, ensuring that Square remains usable and accessible in high-stress emergency scenarios. For future testing, a more comprehensive approach would strengthen findings and recommendations. A more extensive user testing should involve a larger and more diverse participant group, particularly professionals working in emergency management, to provide deeper insights into how Square can be improved to effectively meet the user needs. Additionally, a team of expert evaluators with knowledge on emergency management as well as universal design and situational disabilities should conducting heuristic evaluations and manual accessibility testing.

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